SPACAL test beam data & simulation need

Jin Huang   (BNL)

Overview / summary

- Test beam simulation status
- Experience from eRD1 2014 test beam comparison
- Data required for simulation tuning
  - Beam composition, position distribution, background, purity, and energy spread
  - Electron shower studies
  - Hadronic shower studies
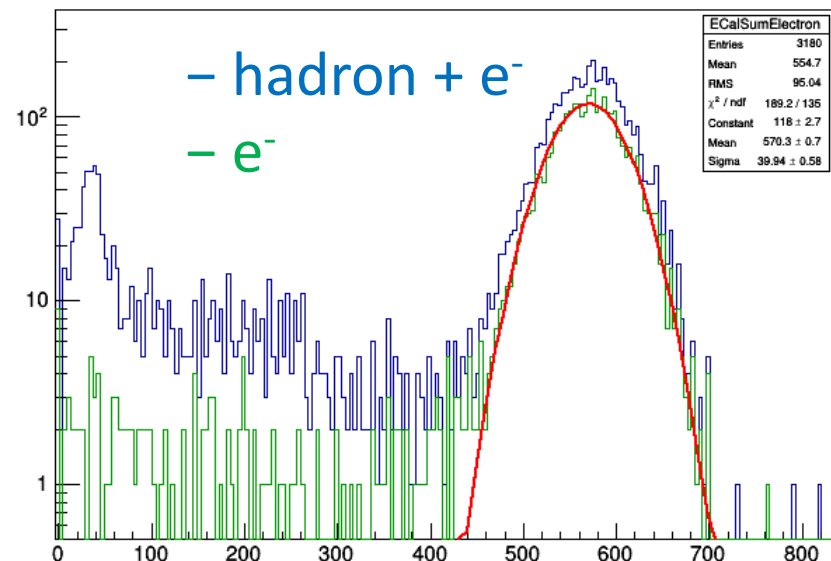 - Tunneling effect

What we have/haven't implemented

- Beam momentum spread, position spread and multi-species
  - 2.4% for 8 GeV/c beam, 2.7% for 4 GeV/c beam
- Active volume
  - Tunable size/matrix/fiber specifications/fiducial region
- Baseline simulation configuration, which is also tunable
  - Hadronic model: QGSP_BERT_HP
  - Light production: Geant4 default Birk model (G4EmSaturation::VisibleEnergyDeposition)
  - Group Geant4 hits into fibers then into towers
    - Possible to use measured fiber-fiber light variation map
  - Digitalization with test beam performance:
    - photon fluctuation (500p.e./GeV, Poisson model)
    - Pedestal noise (2ADC)
    - Zero suppression of (4ADC)

- Need to finalize geometry with Hcal simulation

Last study: eRD1 2014 1D proj. SPACAL

- Obtained eRD1 2014 beam test geometry and data with many help from Oleg Tsai, Alex Kiselev and Craig Woody
  ◦ Diff with sPHENIX test beam device: fiber choice, SPACAL vendor, electronics
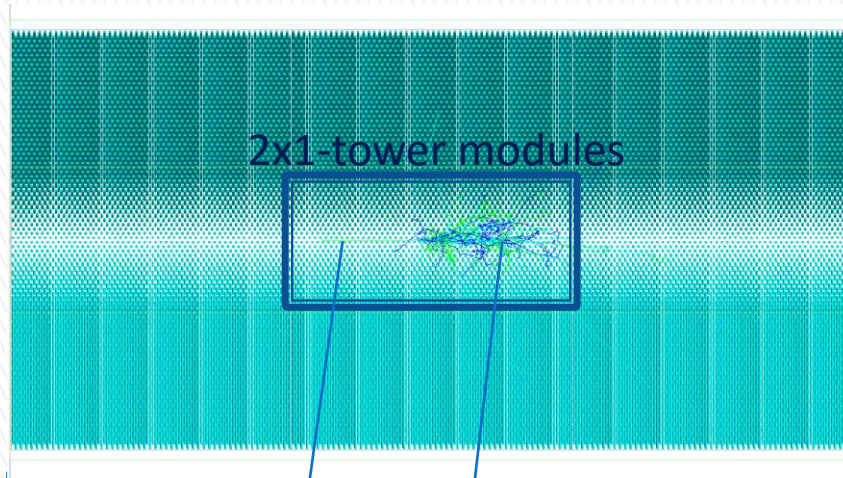- Implemented in Geant4 -> SPACAL towering -> digitization
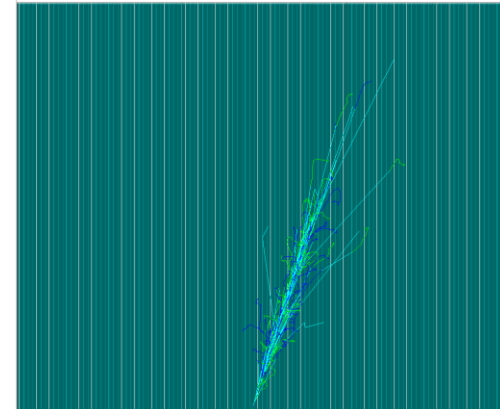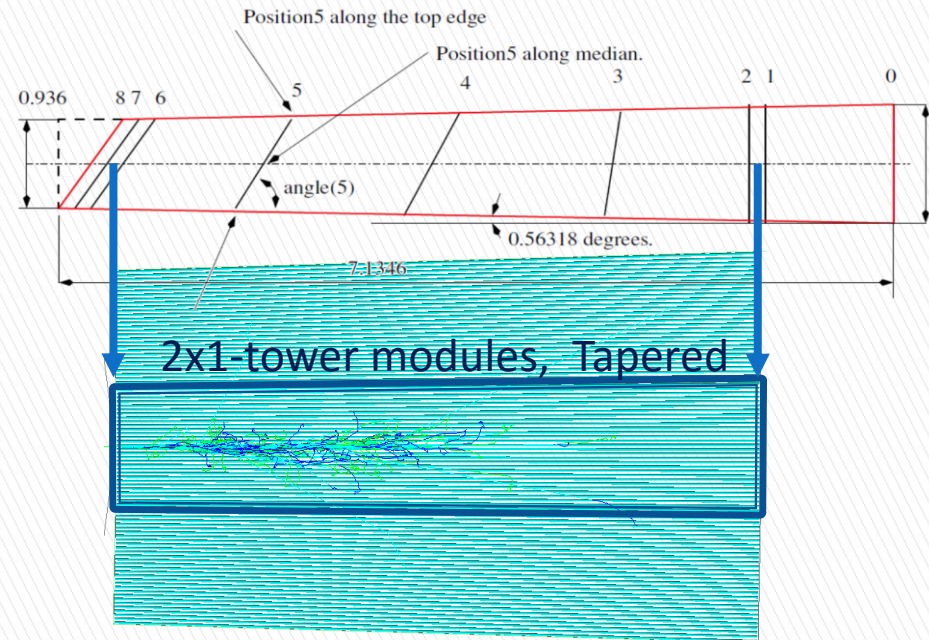
SPACAL prototypes in 2014 Fermilab beam test

Barrel SPACAL
EIC RD1 Collaboration

– hadron + e⁻

– e⁻

Courtesy : O. Tsai (UCLA)

Test beam in G4
1D fiber, parameter tunable

2x1-tower modules

2x1-tower modules, Tapered

Position5 along the top edge
Position5 along median.

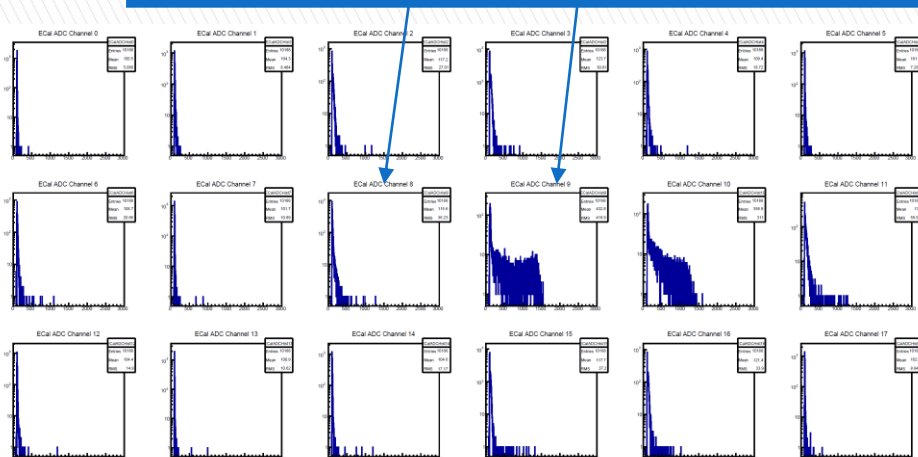0.936   8 7 6   5   4   3   2 1   0

angle(5)

0.56318 degrees.

7.1346

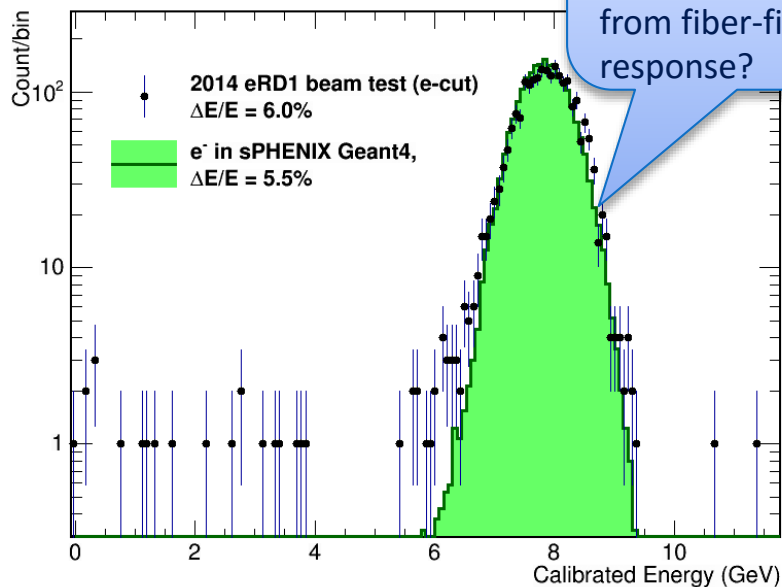Particle view
(half cm front Al cover not shown)

Side views
(17 degree indenting as in test beam, 2.4-2.7% energy spread and half-cm front Al cover not shown)
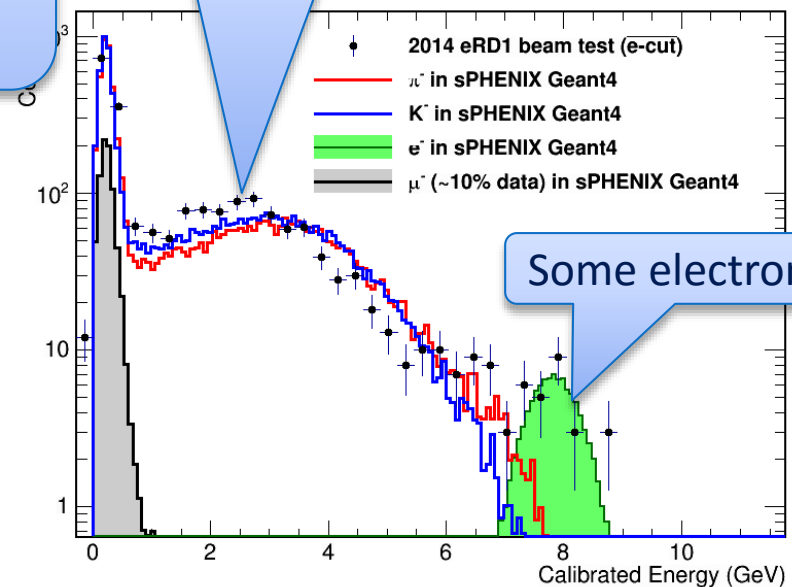
Beam test data, eRD1 2014

Test beam comparison:
8 GeV beams shower in Geant4 VS data

Very good matching in line shape.
Data: slightly more fluctuation (<10% rel.) from fiber-fiber response?
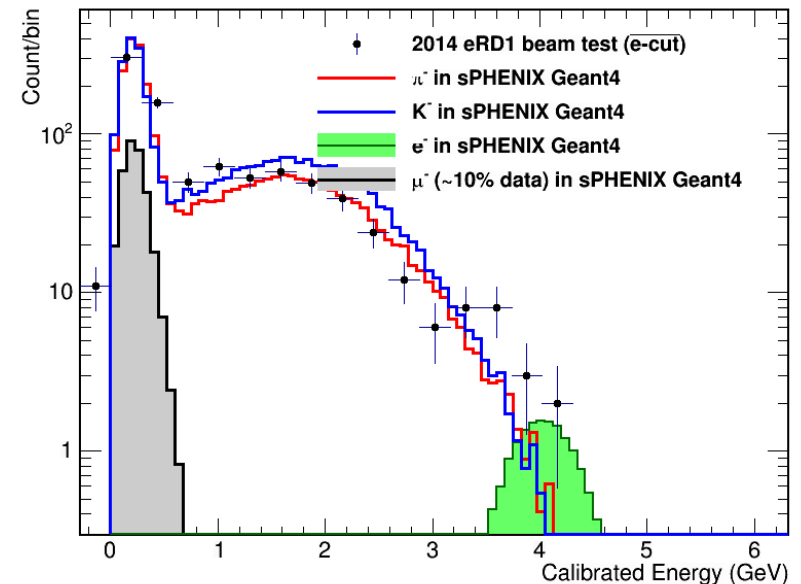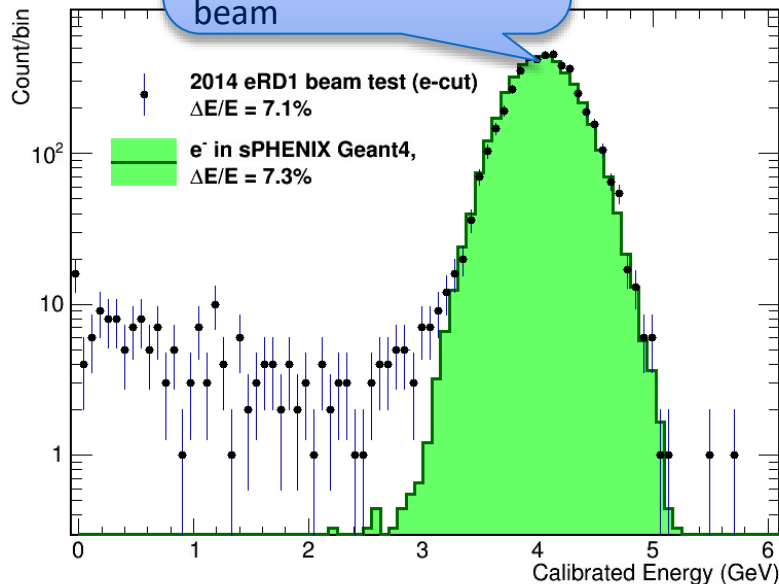
Less response in data? Proton component?

Some electron left

Full Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
Pedestal noise (2ADC), photon fluctuation (500e/GeV), NO fiber/fiber response
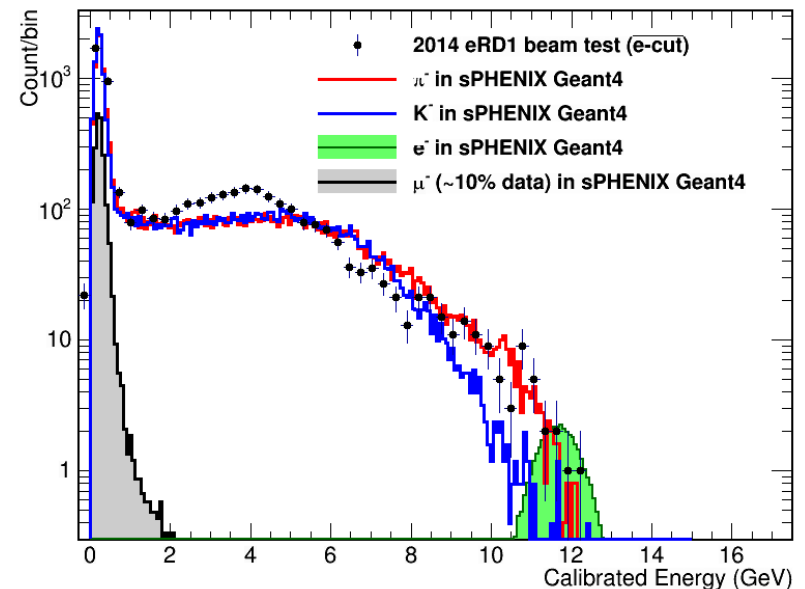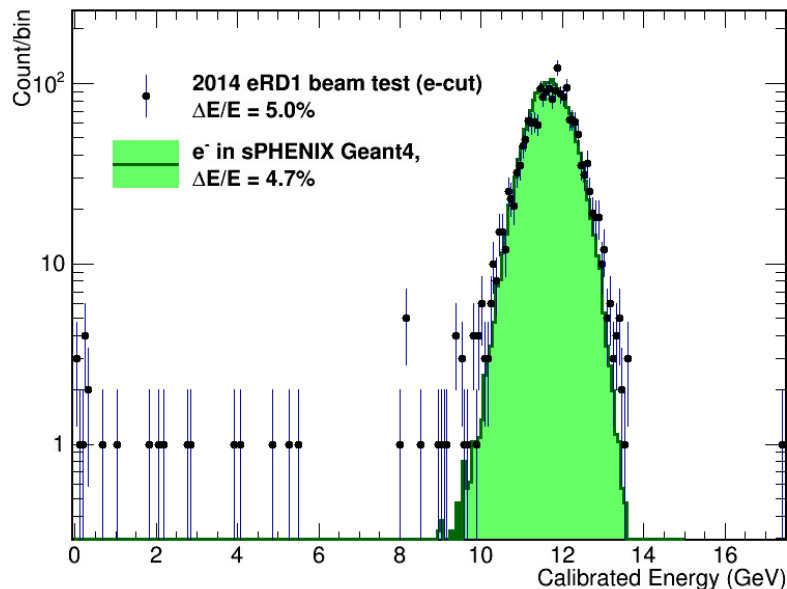
Test beam comparison:
4.12 GeV/c beams shower in Geant4 VS data

Linearity reproduced with energy scale calibration from 8GeV beam for 4.12 GeV/c beam

Full Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
Pedestal noise (2ADC), photon fluctuation (500e/GeV), NO fiber/fiber response

Test beam comparison:
12 GeV/c beams shower in Geant4 VS data

Full Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
Pedestal noise (2ADC), photon fluctuation (500e/GeV), NO fiber/fiber response

What data we need from the test beam

»

Needed from test beam: beam data

- Need to verify composition not significantly changed
- What about proton/anti-proton composition in "pion"?

sPHENIX beam test, Liang, Xiaochun and John H.

Test Beam Composition:

	4 GeV	8 GeV	16 GeV	25 GeV	32 GeV	40 GeV	50 GeV	60 GeV
pion	32.1%	39.8%	67.2%	85.7%	91.9%	94.6%	96.5%	97.2%
electron	63.7%	56.4%	26.1%	8.9%	3.7%	1.6%	0.6%	0.3%
muon	4.2%	3.8%	6.7%	5.4%	4.4%	3.8%	2.9%	2.5%

CALICE test, cited via FTBF cite (http://ftbf.fnal.gov/)
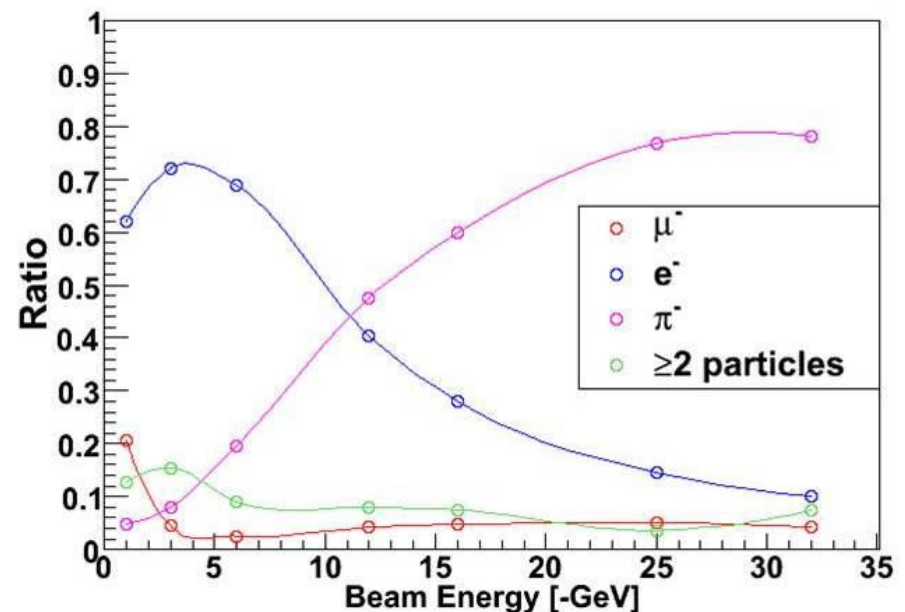
Needed from test beam: Electron response

- Linearity and resolution
- Also for tapered SPACAL, energy scale VS indenting angle
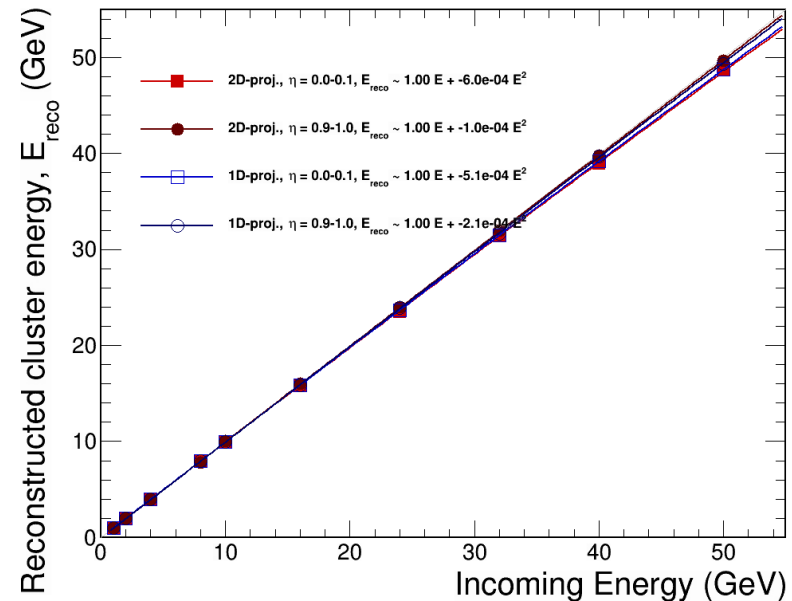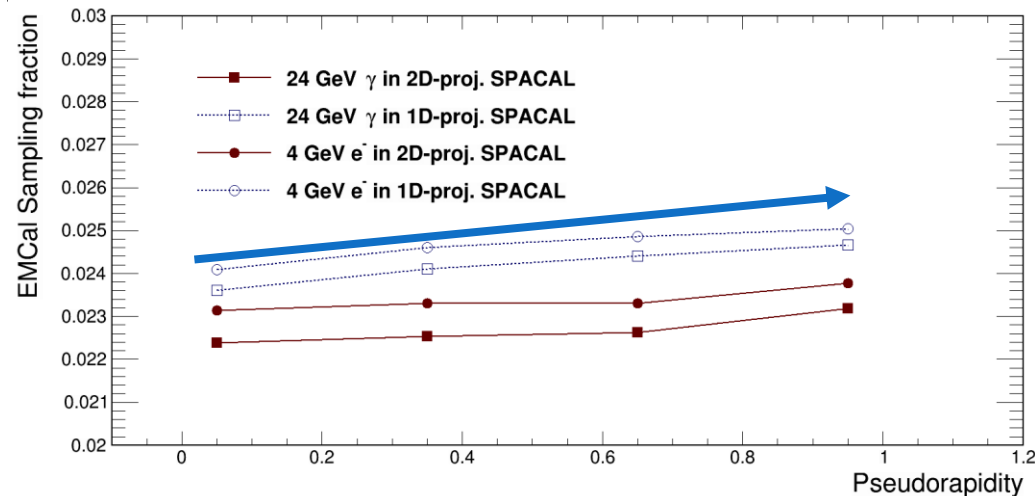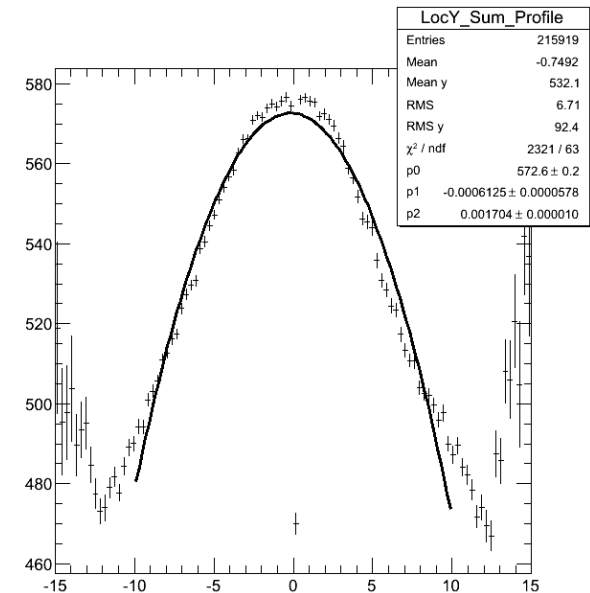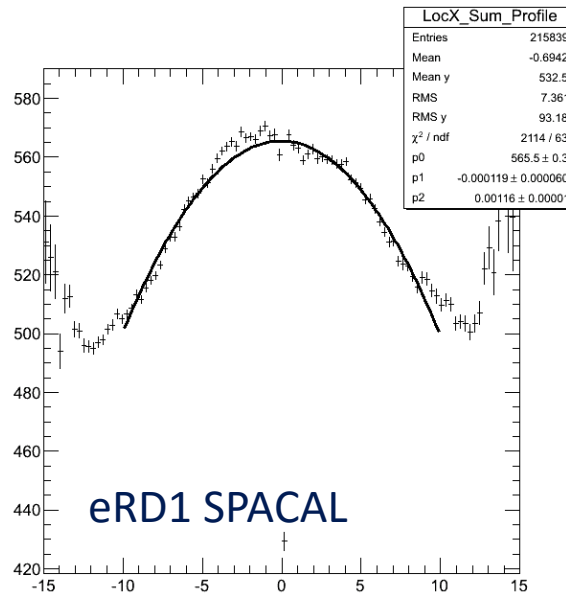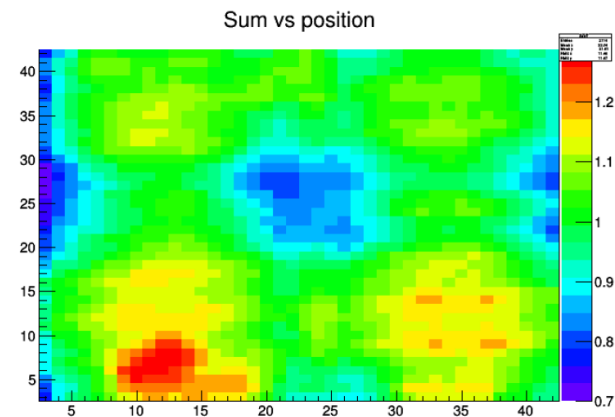
Needed from test beam: Position response

- Quantify lateral positional dependence via photon collection eff. and fiducial area at the edge
- Verify longitudinal position dependence via fiber light attenuation, possible damage and cladding light.
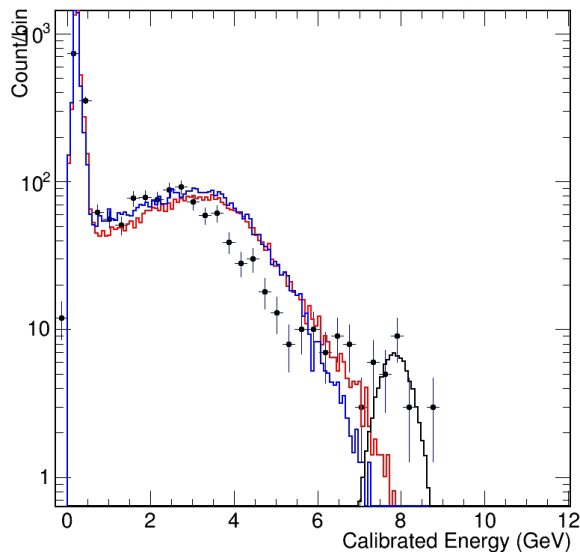- Both associate with additional constant term and high energy performance

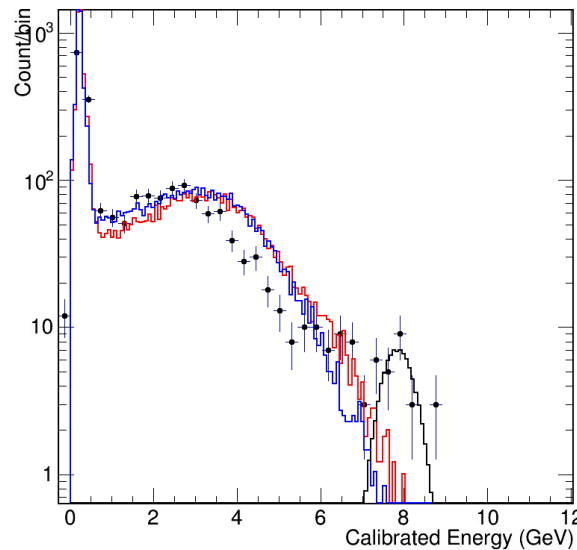eRD1 SPACAL, UV photon scan

eRD1 SPACAL

Needed from test beam: Constraint hadron model

Hadron response are open for many tunings, need clean hadron data to do so
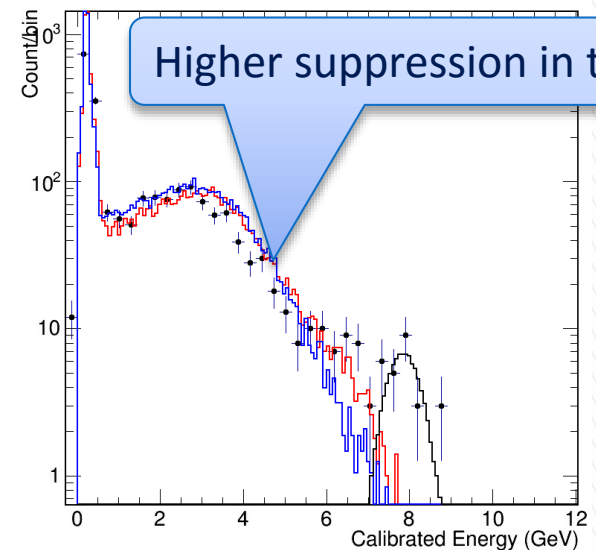Again, any proton/anti-proton component would behave very differently

Pion- (red) K- (blue) e contaim. (black) Sim VS data

Higher suppression in tail

Default configuration
production threshold of 1mm,
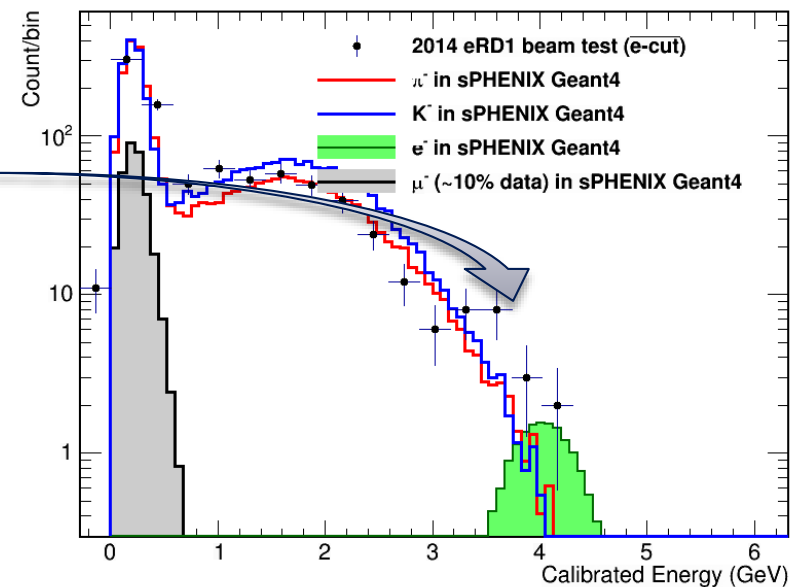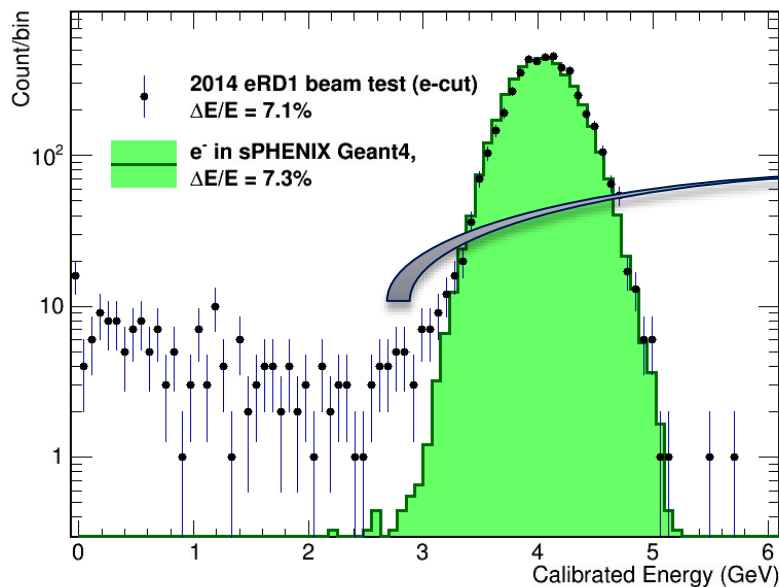Birk constant = 0.00794 cm/MeV

Baseline configuration
+ production threshold of 1um

Baseline configuration
+ CALICE Birk constant
0.0151 cm/MeV

Needed from test beam:
Clean beam tagging to pin down rare hadron shower

- Beam background as illustrated in electron sample also expected in the hadron sample
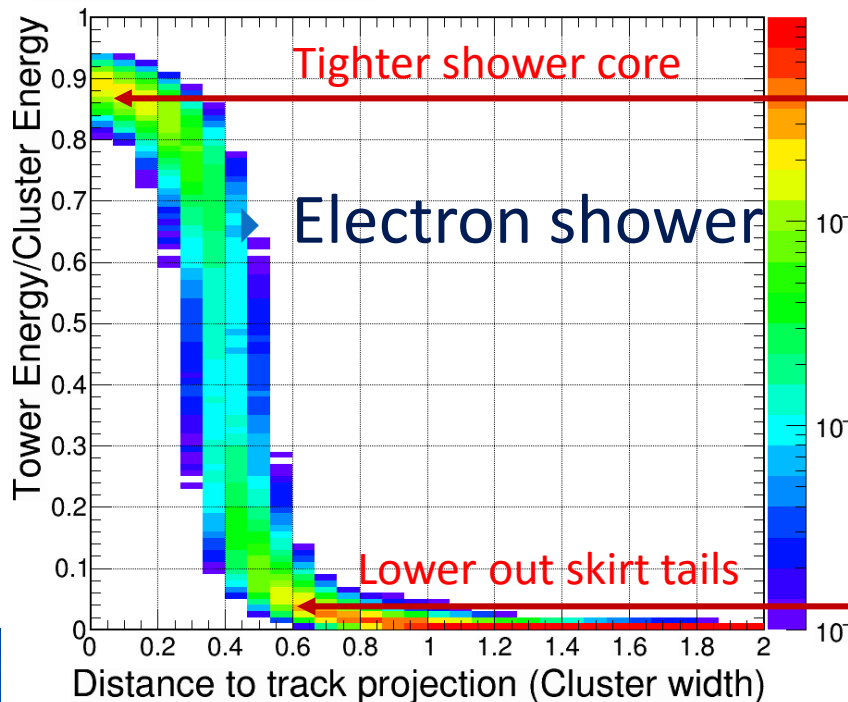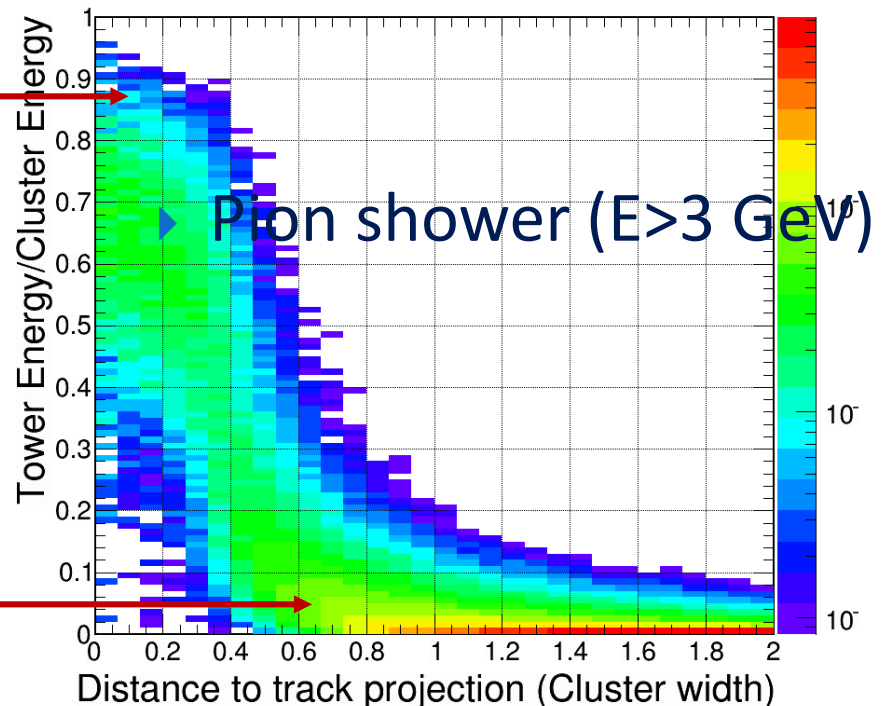- Unfortunately, we are looking for <10^-2 rare hadron shower

Needed from test beam:

Shower shape verification

▸ For more advanced hadron rejection require shower shape analysis. Unfortunately it is more depending on reliability of hadronic shower simulation.

▸ Test beam data with tracking precision of <~2mm could pin down this uncertainty.

Needed from test beam: Tunneling effect in fiber view orientation

- In Geant4 we use straight fibers, however in reality they are likely to be wavy depending on construction procedure.
- For straight fibers, 20% of straight track would tunnel through the SPACAL, producing tails. Could be a problem for photon measurement
- Do we see that in prototype? Shall we make our fiber wavy in simulation?

Larger leakage from proj. fiber

3.6% of photons
Leakage > 80%

p_T = 4GeV/c particles in sPHENIX field
-5 cm < vz < 10 cm, 0<eta<1

8% of photon leave 80-90% energy in EMCal
-> kinematic smearing in gamma-Jet measurements

Energy Deposition in EMCal (scint. + abso.) / Total Energy

Extra information

>>